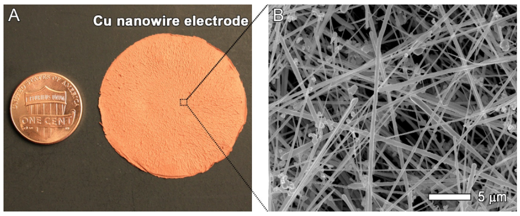
A high-surface area, highly conductive three-dimensional porous electrode

Unmet Need

Electrochemical reactors involve conversion between electrical energy and chemical. Flow electrochemical processes are used in many electrochemical reactor applications such as reduction-oxidation (redox) batteries, water treatment systems, electrochemical sensors, and electrochemical organic synthesis. It would be advantageous to use the periodic oversupply of solar energy in new electrochemical processes. For example, the amount of wasted renewable power by the California independent system operator (CAISO) has increased from 188 GWh in 2015 to 461 GWh in 2018 simply because it's the lowest cost solution to manage the large glut of solar power acquired during the day. The use of otherwise wasted solar power for organic electrochemistry would have the twofold benefit of (1) providing an additional revenue stream to solar power generators and (2) replacing toxic oxidants and reducing agents with renewable electricity. One of the hurdles to increasing the utilization of electricity for chemical production is the volumetric productivity of electrochemical processes (i.e., the production rate of product per unit volume) scales with the surface area of the electrode, rather than the volume of the reactor. As a result, industrial electrochemical reactors tend to be much larger and more expensive than heterogeneous gas-phase or homogeneous chemical reactors for a given rate of chemical production. Partly for this reason, only one (adiponitrile) of the several hundred organic chemicals that are produced at a scale exceeding 104 tons per year is made with an electrochemical process. Increasing the volumetric productivity of electrochemical processes, and thus their economic benefits, has long been a central goal of electrochemical engineering.

Technology

Duke inventors have developed a three-dimensional porous electrode intended to improve the performance of a variety of electrochemical processes, including organic electrosynthesis, water electrolysis, water treatment, fuel cells, and redox flow batteries. This electrode consists of metal nanowires with a specific surface area of 2.4×106 m^2/m^3 and a conductivity of



Duke File (IDF)

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7×105 S/m, values that are 15 time and 33 times higher than carbon paper, the highest surface area porous electrode currently available commercially. The inventors have demonstrated this technology by developing a Cu nanowire felt, made from nanowires 45 times smaller than the 10 µm wide fibers in carbon paper, that can achieve a productivity 278 times higher than carbon paper for mass-transport-limited reduction of Cu ions. Additionally, an electroorganic intramolecular cyclization reaction with Cu nanowire felt achieved a productivity 4.2 times higher than that of carbon paper.

Advantages

- Increases the volumetric productivity of electrochemical processes which could reduce the size and cost of industrial electrochemical reactors
- Enables the use of greener reagents, such as solar energy, to achieve large chemical reactions
- Have demonstrated a 278-times productivity improvement compared to carbon paper

Publications

- Metal Nanowire Felt as a Flow-Through Electrode for High-Productivity Electrochemistry (ACS Nano, 2019)
- US Patent Application 16/373,466